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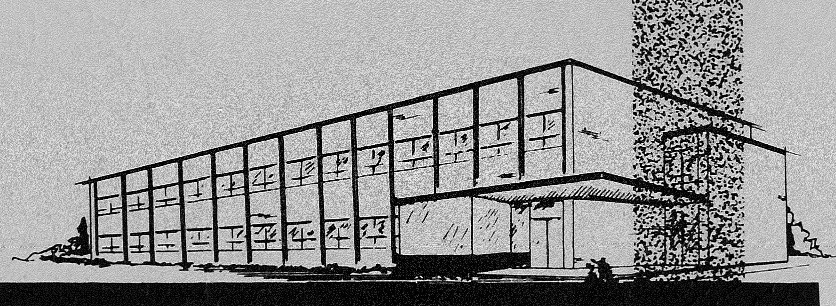
BSR-1195
SOLAR INTERFERENCE WITH LUNAR COMMUNICATIONS (1968-1973)

22 October 1965



THE Bendix CORPORATION

BENDIX SYSTEMS DIVISION · ANN ARBOR MICHIGAN

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SOLAR INTERFERENCE WITH LUNAR COMMUNICATIONS (1968-1973)

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ILLUSTRATIONS

SOLAR INTERFERENCE WITH LUNAR COMMUNICATIONS (1968-1973)

ABSTRACT

Preliminary calculations are made to determine the effect of solar radio interference on reception from lunar-based transmitters. The magnitude of the noise received from the sun is calculated. Based on an assumed antenna gain pattern, an estimate is made of the proximity with which a 30-foot parabolic antenna may be pointed toward the sun without exceeding certain noise criteria. Finally, the near eclipses of the sun by the moon are plotted to demonstrate the frequency of occurrence of potential solar blackouts of lunar communications and the duration of each blackout.

SOLAR INTERFERENCE WITH LUNAR COMMUNICATIONS
(1968-1973)

SECTION 1

INTRODUCTION AND SUMMARY

This study was undertaken as part of the Apollo Lunar Scientific Experiment Package (ALSEP) program to determine whether the RF radiation from the sun poses a problem in that it might interfere with signals being transmitted from a lunar vehicle or base.

1.1 Study Objectives

It was the purpose of this study to identify

a. The magnitude of radio frequency interference contributed by the sun to a communication system typified by that used in the Manned Space Flight Network

b. Those periods (if any) during the years 1968 through 1973 when this solar interference would be of such a magnitude as to disrupt normal communication.

1.2 Method of Approach

To reach these objectives it was necessary to undertake the following tasks:

a. - Determine the nature and magnitude of solar radio interference

- Compute the noise power in a system similar to the MSFN as a result of solar interference

- Provide a preliminary estimate of the minimum angle between the boresight of the antenna and the limb of the sun at which communications with a lunar station would be satisfactory

b. - Obtain ephemeris data relevant to the moon/earth/sun geometry suitable for computing the elongation of the moon from the sun for the years of interest

- Identify those particular intervals during which the elongation angle of the moon/sun is less than the angle for satisfactory communications identified in "a" above.

1.3 Summary of Results

The results of this investigation indicate that a communications system having a 30-foot parabolic antenna will satisfactorily receive signals from a 1-watt lunar transmitter at angles greater than 1 degree from the sun's limb. It is also shown that a solar blackout may exist for up to six hours at one time but in general there will not be more than four solar blackouts per year.

SECTION 2

THE MAGNITUDE OF SOLAR INTERFERENCE

2.1 Solar Radio Interference

The spectral intensity, F, of radiation of frequency, f, from the quiet sun is related to the electron temperature, T, as follows (Reference 2):

$$F = 2.09\,(10)^{-32}\, f^2\, T \text{ watts}/\text{m}^2/\text{cps} \qquad f(\text{mc})\ T(^\circ\text{K})$$

At a radiation frequency of 2300 mc the temperature of the sun has been measured by Jet Propulsion Laboratory (Reference 3) to be 50,000°K.

This yields a spectral intensity of

$$5.5\,(10)^{-21} \text{ watts}/\text{m}^2/\text{cps}$$

as the solar radio interference at the input to an earth-based communication system. It should be noted that the high sky noise condition considered in Reference 1 corresponds to an electron temperature much lower than that of the sun. The following analysis is presented to indicate, in terms of the power budget of Table 1 in Reference 1, the magnitude of radio interference contributed by the sun when the MSFN antenna is directed away from the limb of the sun by an angle greater than the first null in the gain pattern.

2.2 Solar Interference with a 30-foot Parabolic Antenna

In lieu of the actual characteristics for the MSFN antennas of interest, values of typical, well designed, 30-foot parabolic antennas were used in the following evaluation. These values were as follows:

Gain - Boresight: 44 db

- 1st sidelobe (1.4°): 24 db

Effective area: 33.6 sq. meters

Under these conditions the spectral intensity of solar noise is

$1.85\ (10)^{-19}$ watts/cps (-163 dbm) for main lobe

$1.85\ (10)^{-21}$ watts/cps (-183 dbm) for first sidelobe

In addition, a receiver bandwidth of 50 cps was used, as in Reference 1.

It should be noted that the sun was considered to be a point source of radiation although it actually subtends a total angle of slightly greater than 1/2 degree at these radio frequencies. This consideration presents a slightly exaggerated indication of the actual variation of solar noise input with changing antenna angle since it does not take into account the comparable angular size of the antenna lobes and the solar disc, the variation of radiated power from various portions of the solar disc, or, the fact that differing gain figures would apply to energy coming from these various portions for a given pointing angle. In its simplest form, the energy coming from the sun is considered to be emanating from a point source located on the relevant lobe axis whenever that lobe is directed within the sun's disc. When the lobe axis is not pointing at the sun, the gain pattern is considered to be a function of the angle from the axis to the nearest limb of the sun.

2.3 Power Budget

Table 1 below uses these solar noise figures to provide a comparison with the nominal-case power budgets for 30-foot antennas given in Reference 1. The item numbers correspond with those in Reference 1.

Item	Boresight	1st Sidelobe
6. Noise Spectral Intensity	-163 dbm/cps	-183 dbm/cps
14. Noise bandwidth (50 cps)	17 db	17 db
15. Net noise (6 + 14)	-146 dbm	-166 dbm
16. Required SNR	12 db	12 db
18. Threshold Carrier Power (15 + 16)	-134 dbm	-154 dbm
17. Received Carrier Power	-137 dbm	-137 dbm
19. Carrier Margin (17-18)	-3dbm	+ 17 dbm

TABLE 1

Power Budget and Solar Interference

2.4 Solar Blackout Limit

It is evident from the above power budget that only the primary lobe of this hypothetical 30-foot parabolic antenna has enough gain to raise the solar radio noise above the minimum permissible level. Since the first null of a typical antenna of this form occurs at approximately 1 degree from the boresight axis, a general rule of thumb (of use if the actual gain patterns are not available) can be to conclude that solar noise is not appreciable at pointing angles greater than 1 degree from the limb of the sun.

SECTION 3
PERIODS OF SOLAR BLACKOUT

To determine when solar interference will be a problem to a communications antenna pointed at the moon it is necessary to compute from ephemeris tables the angle subtended at the earth by the lines of sight to the moon and the sun at any specific time. Tables are published annually by the U.S. Naval Observatory Nautical Almanac Office giving the ephemerides of the sun and moon. Specifically, the longitude and latitude of these bodies are listed. Because the latitude of the moon seldom exceeds 5 degrees, the angular separation of the moon and sun can be determined by differencing these tabulated latitude and longitude values.

Since it was not possible to obtain the lunar ephemerides as computed for the years 1968 through 1973, it was necessary to extract the required data from ephemeris tables for the years 1950 through 1955. This is possible, to a high degree of accuracy, due to the fact that the earth/moon/sun angular relationship repeats itself every 6585.32 days (called the SAROS). This is equivalent to 18 years plus 10 or 11 days (depending on leap-years).

In Appendix A are presented polar plots of periods of near-eclipse of the sun by the moon during the years of interest. The elongation angles stated are all referenced to an observer (a) at the center of the earth or (b) at the location on the surface of the earth at which the sun is directly overhead. Zero hours Greenwich Mean Time is indicated on each monthly trace for the relevant day of that month. 1200 hours GMT is also indicated. Using this information the referenced location on the Earth's surface ("b" above) can be determined and hence a coarse approximation can be made to yield the angular correction to be applied to the graph data to make it applicable to some other location.

Figure 1 presents a summary of the minimum elongations for the 1968-1973 period. For lunar-mission planning purposes it readily identifies those times in which solar interference may/may not be a problem. If the criteria of 1 degree from the limb of the sun is valid, then it can be determined directly which months of the selected year yield a solar blackout (i.e., all elongations less than 1-1/4 degree). The detail plots in Appendix A may then be referred to, if necessary, to determine the day and the hour of the blackout.

SECTION 4

CONCLUSIONS

This report presents a preliminary estimate of the proximity with which a 30-foot parabolic antenna may be pointed toward the sun without exceeding certain specified noise criteria. It also indicates how often, in the time period 1968-1973, this condition might be exceeded, for an antenna pointing at the moon, through the occurrence of a solar near-eclipse.

Specific calculations, made on the basis of an assumed sun temperature of 50,000°K at 2300 mc and a bandwidth of 50 cps, indicate that only that solar noise received in the main lobe of the antenna ($\pm$ 1 degree) is sufficient to blackout reception from a 1-watt lunar transmitter. For such an antenna pointed at the moon, the sun will also pass within 1 degree of the boresight axis from 2 to 4 times a year. The duration of each blackout can be as long as 6 hours.

It is emphasized that these conclusions are the result of a very cursory analysis and that a number of refinements are possible, such as

- correlation of the solar noise cycle (11 years) with the actual years of interest

- consideration of measured gain patterns for specific antennas.

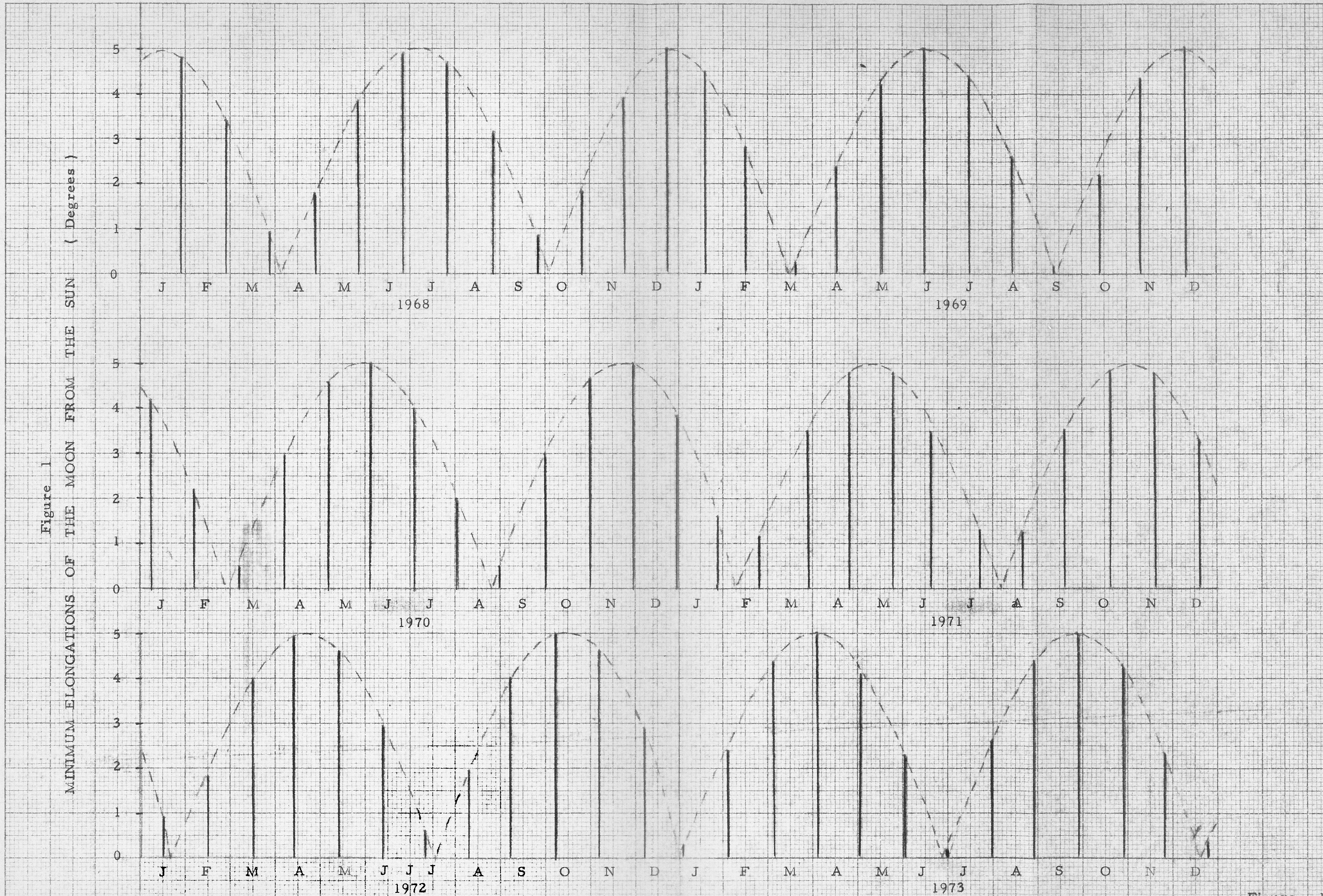

MINIMUM ELONGATIONS OF THE MOON FROM THE SUN (Degrees)
Figure 1
J F M A M J J A S O N D J F M A M J J A S O N D
1968
1969
1970
1971
1972
1973
0 1 2 3 4 5

Figure 1

References

1. ALSEP Review of TRW, TAPLE Report
   Bendix Systems Division No. ATM-18 (9-29-65)

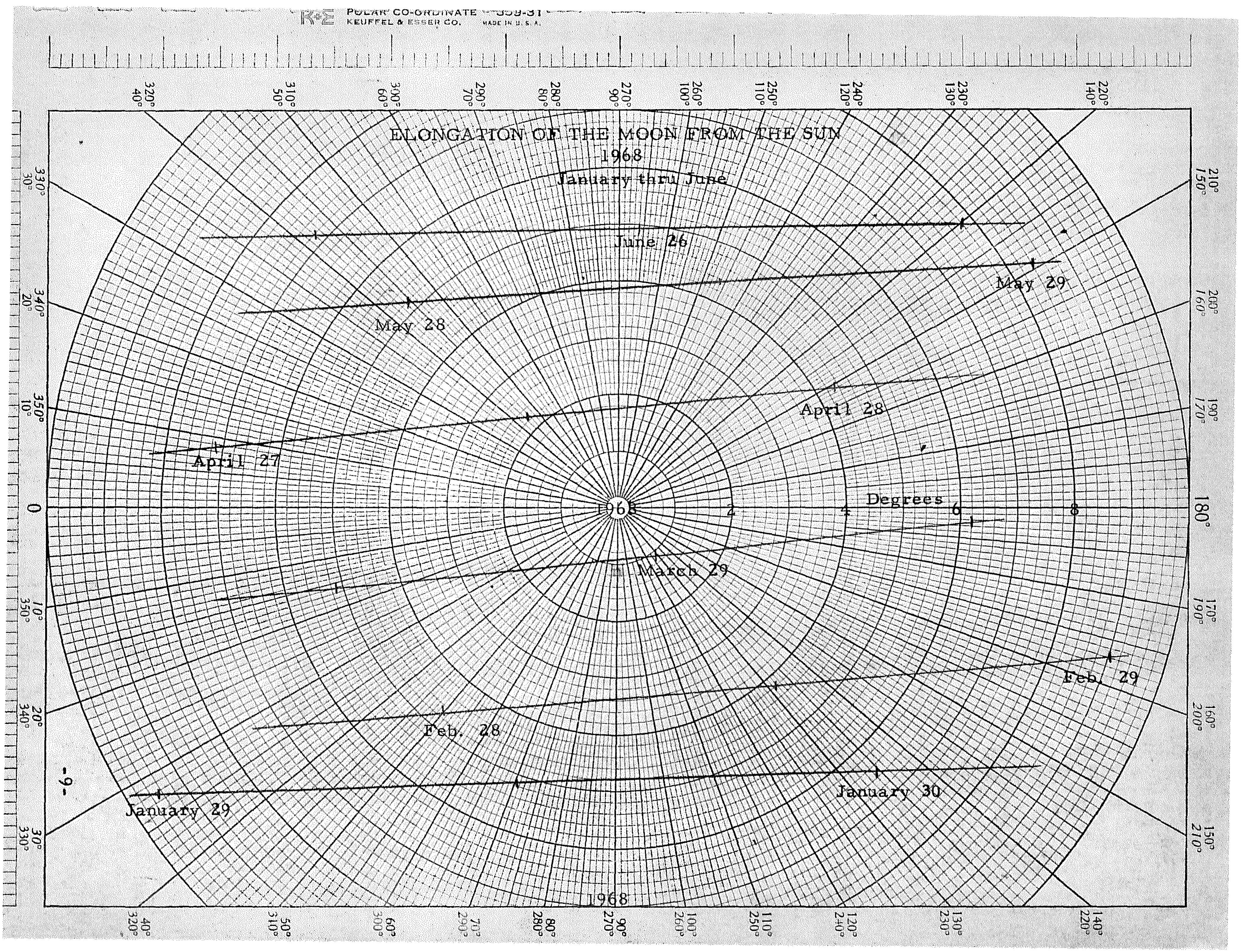
2. Solar Radio Interference as a Function of Frequency
   - IEEE Trans. on Communications Systems,
   Vol. CS-11, No. 1, March 1963, pp 79

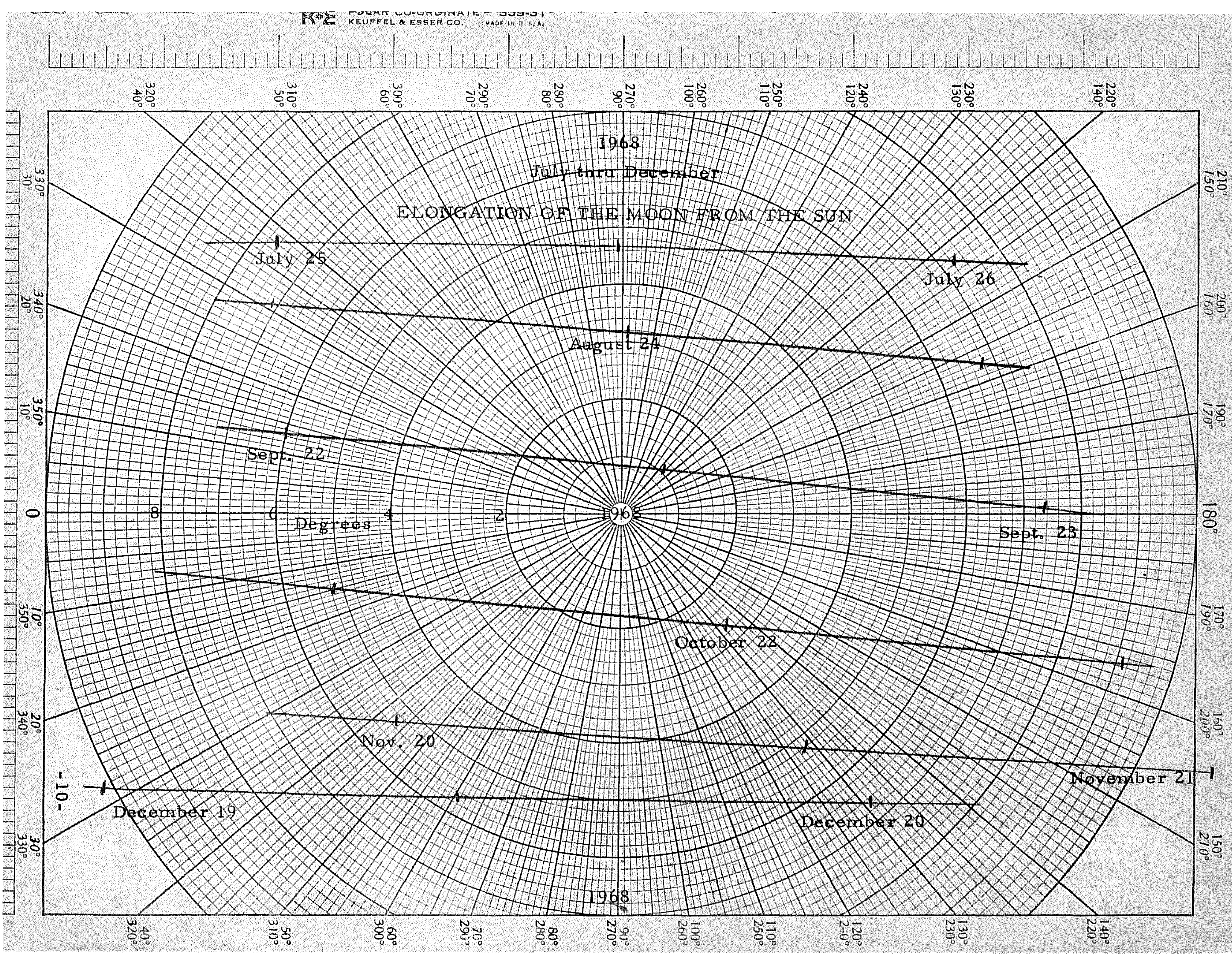
3. System Capabilities and Development Schedule of DSIF
   - JPL Technical Memorandum No. 33-83 (April 1964)

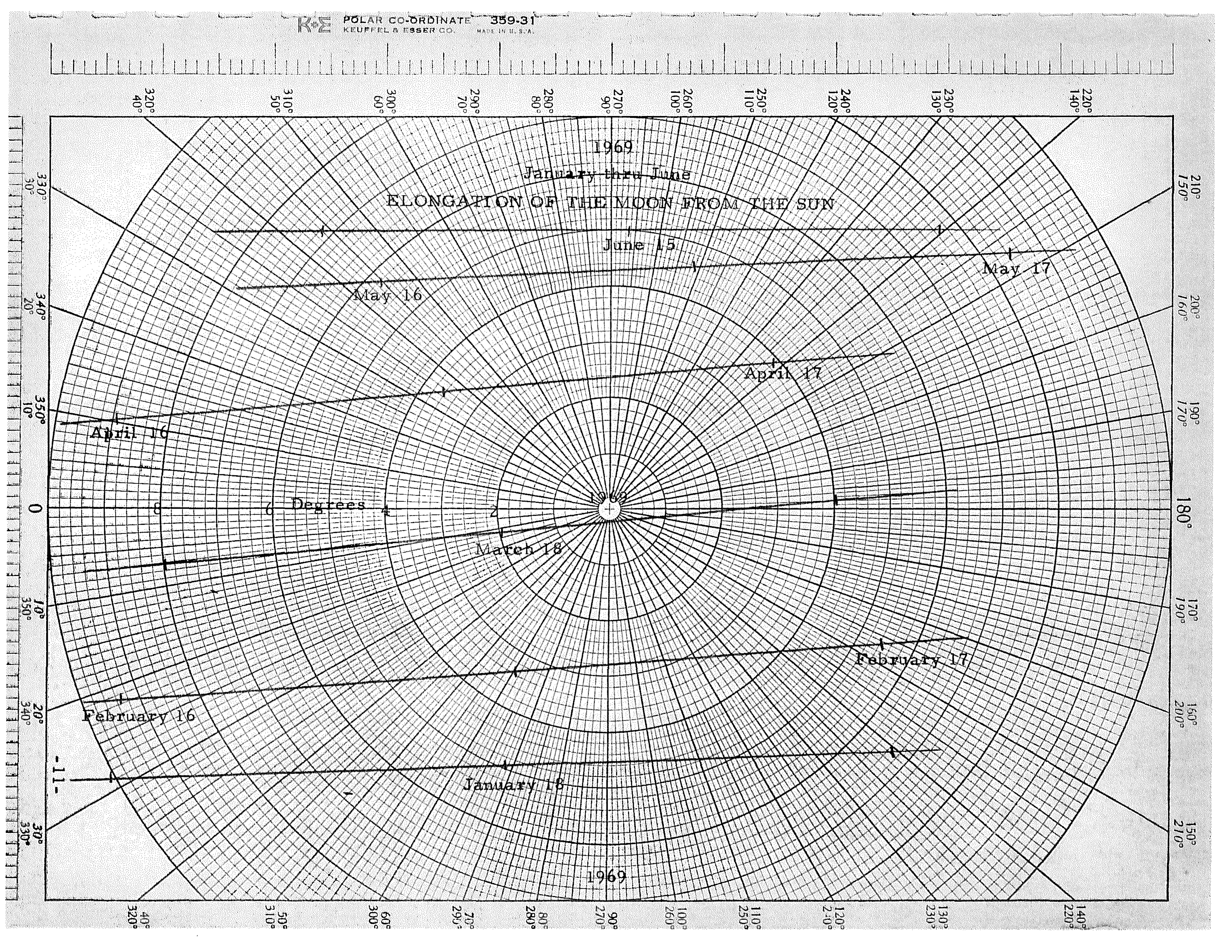
APPENDIX A

ELONGATION OF THE MOON FROM THE SUN

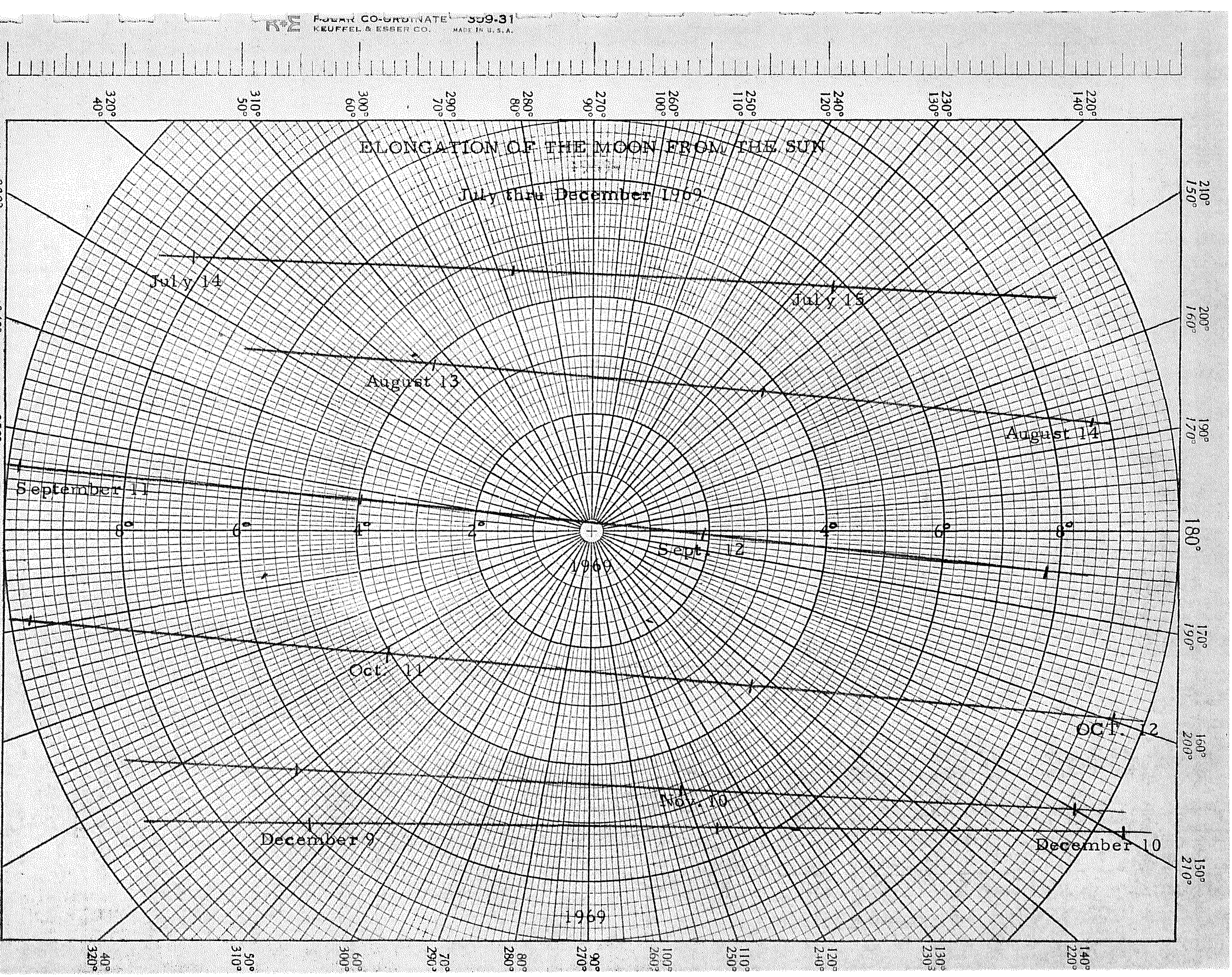
1968 to 1973

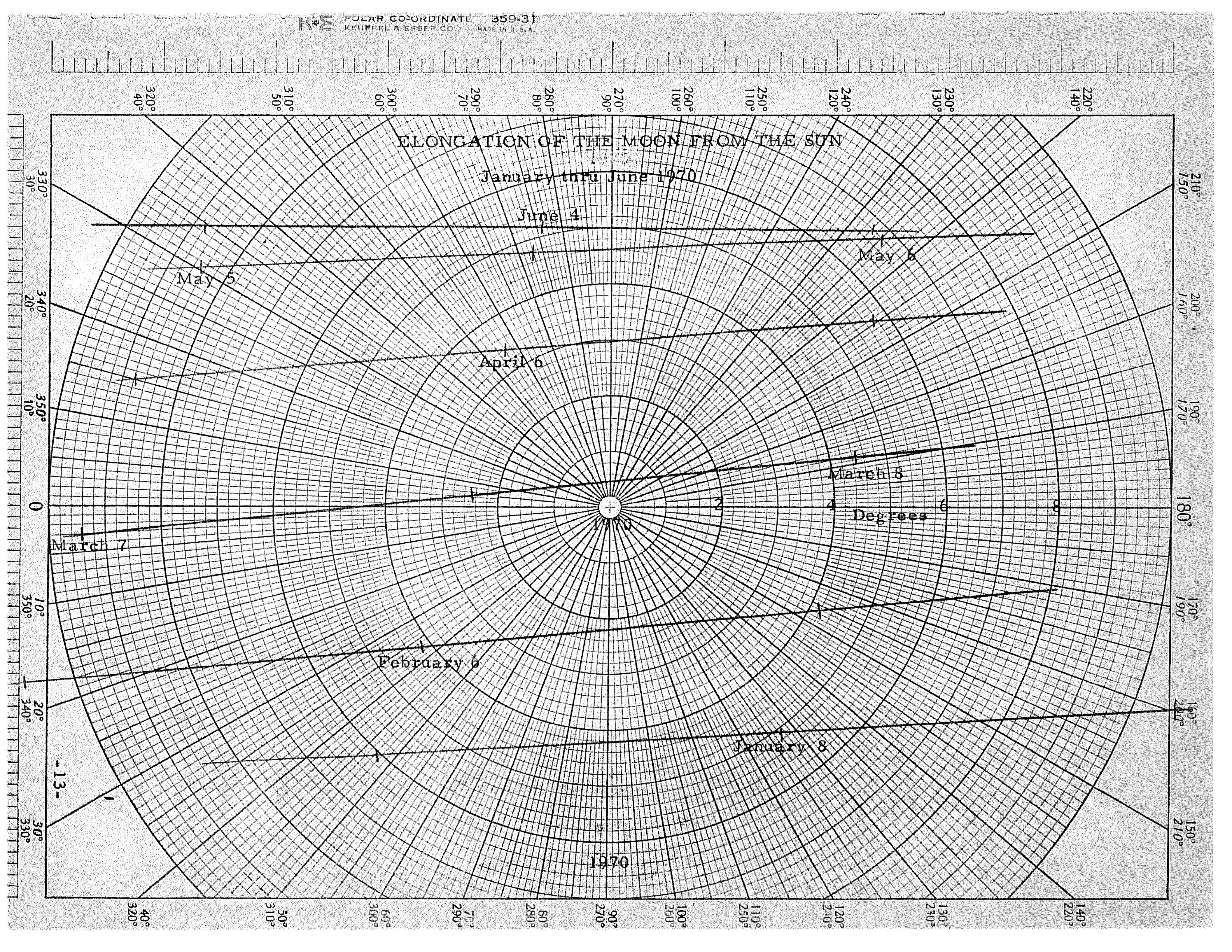

ELONGATION OF THE MOON FROM THE SUN
1968
January thru June
June 26
May 29
May 28
April 28
April 27
Degrees
2
4
6
8
March 29
Feb. 29
Feb. 28
January 30
January 29
1968
KEUFFEL & ESSER CO.
POLAR CO-ORDINATE
MADE IN U.S.A.


KEUFFEL & ESSER CO.
MADE IN U.S.A.
1968
July thru December
ELONGATION OF THE MOON FROM THE SUN
July 25
July 26
August 24
Sept. 22
Sept. 23
8
6
Degrees
4
2
1968
0
180°
October 22
Nov. 20
November 21
December 19
December 20
1968

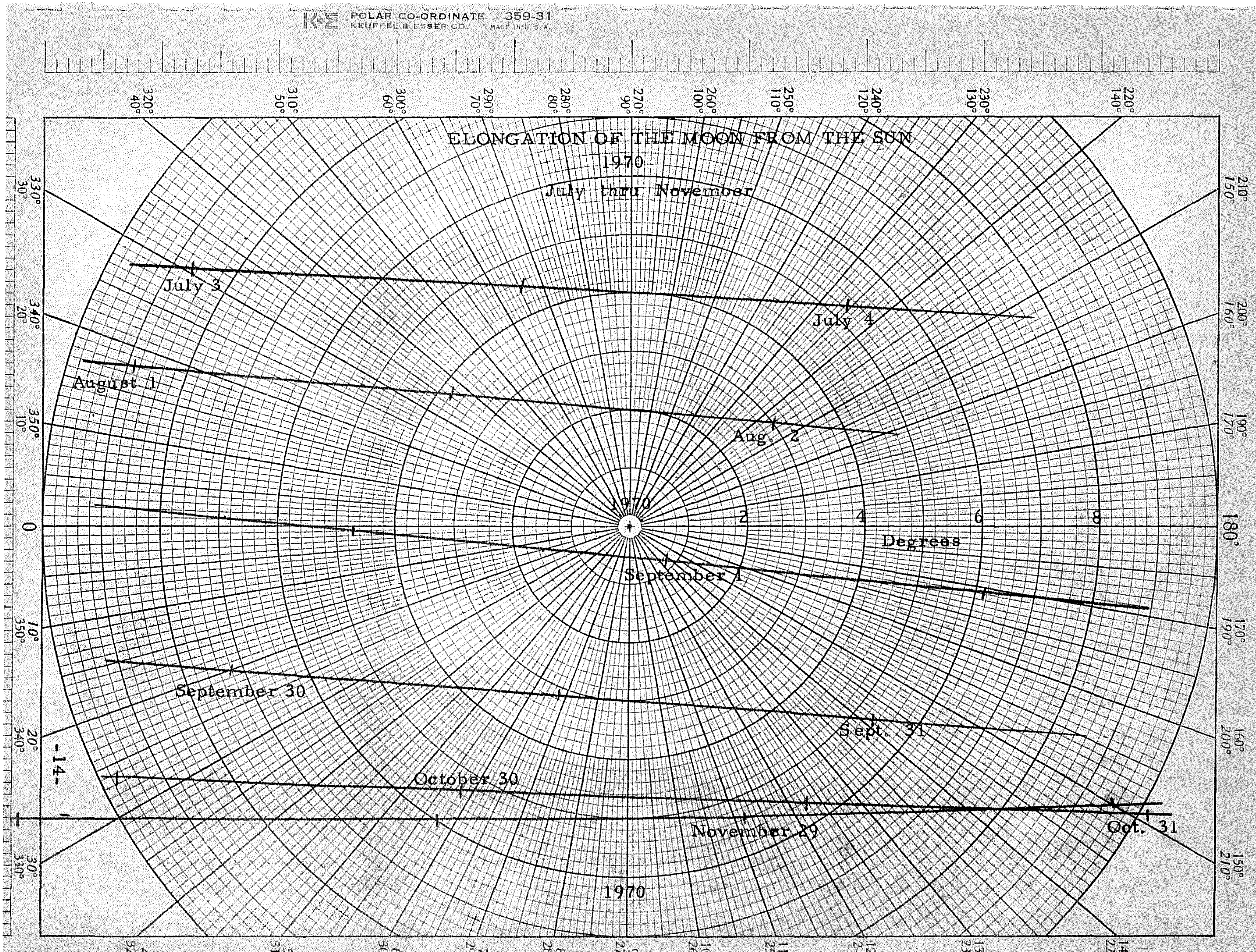


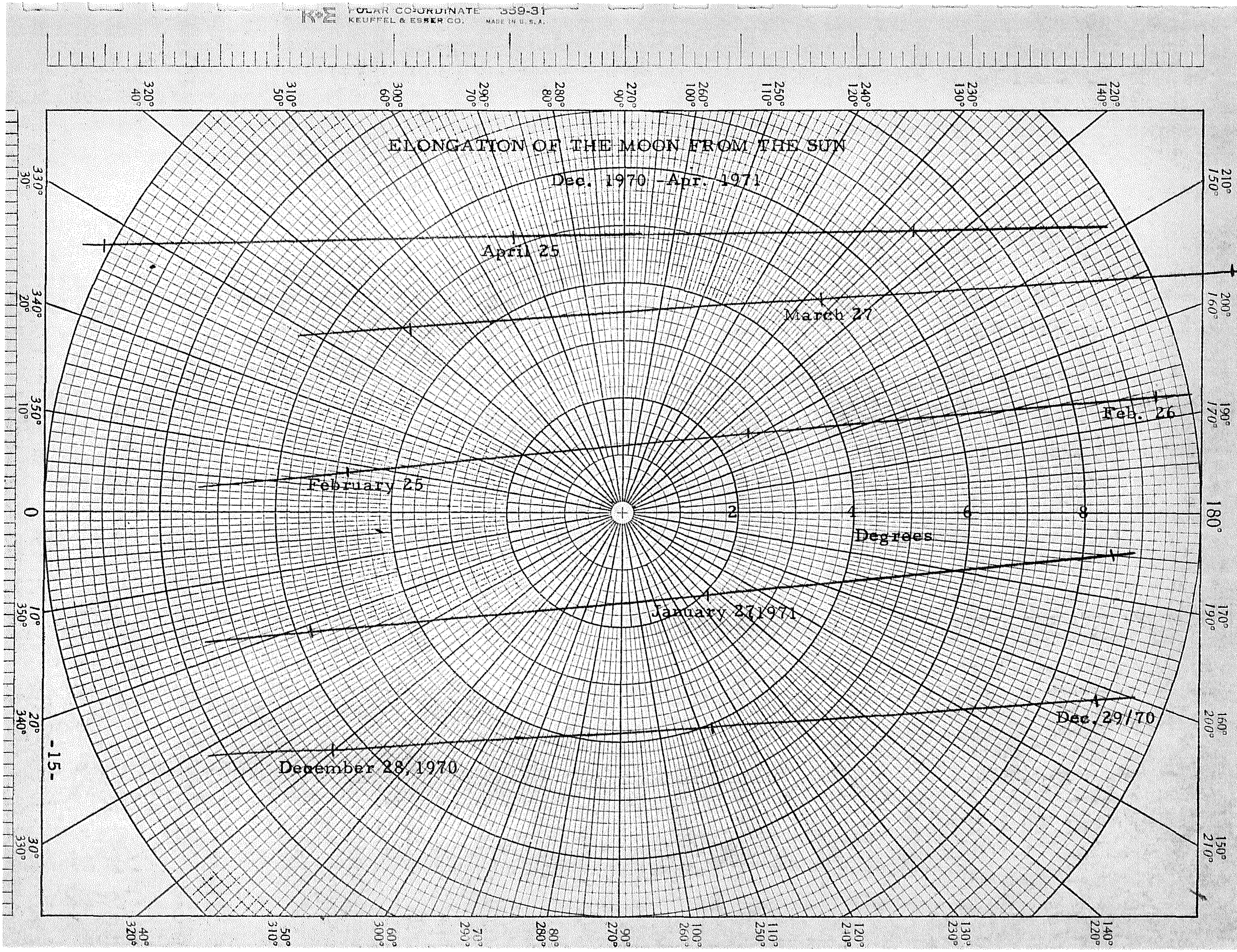
POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO. MADE IN U.S.A.
1969
January thru June
ELONGATION OF THE MOON FROM THE SUN
June 15
May 16
May 17
April 16
April 17
Degrees
March 18
February 16
February 17
January 18
0
180°

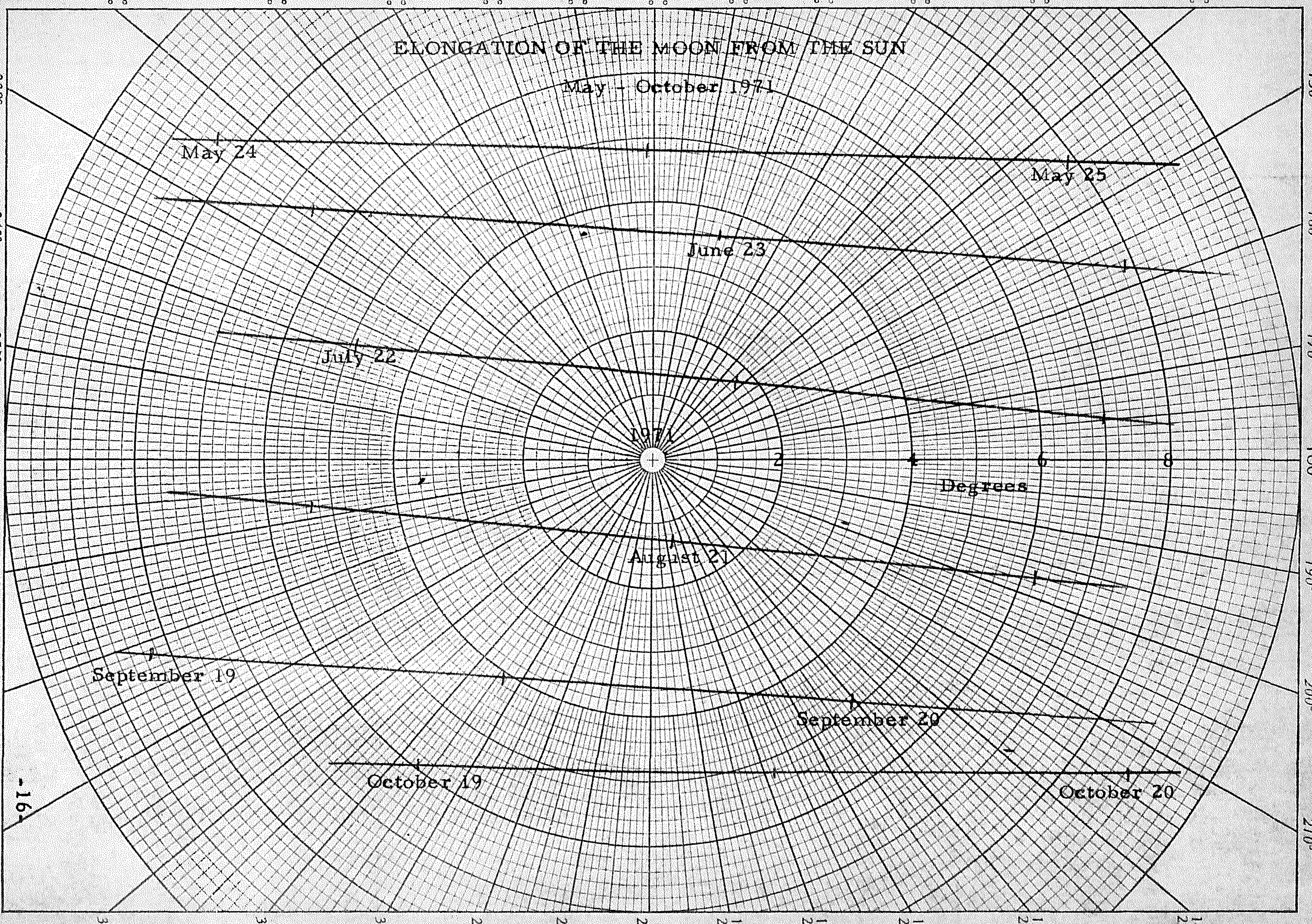

ELONGATION OF THE MOON FROM THE SUN
July thru December 1969
July 14
July 15
August 13
August 14
September 11
Sept. 12
Oct. 11
OCT. 12
Nov. 10
December 9
December 10
1969
1969
KEUFFEL & ESSER CO.
MADE IN U.S.A.



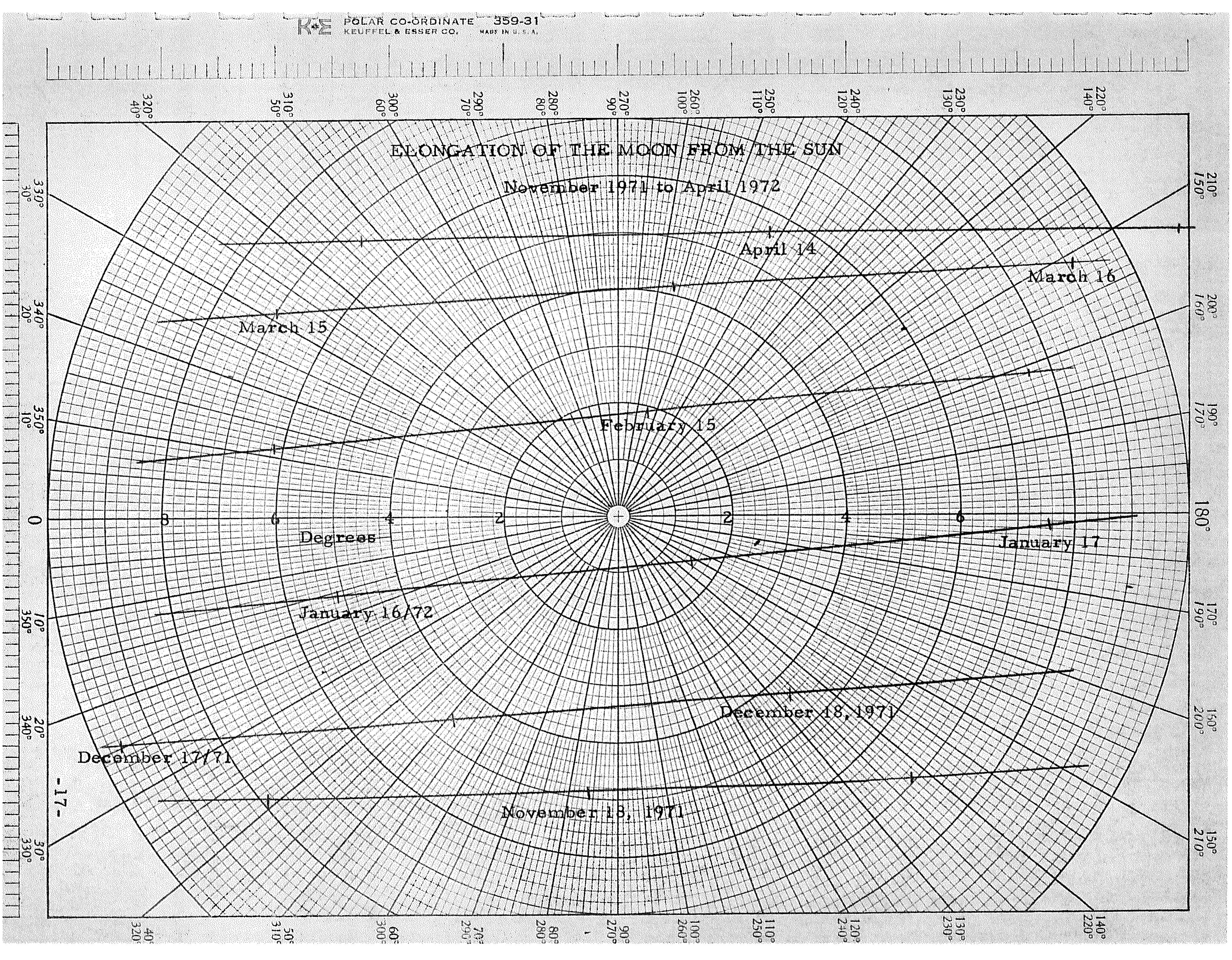
POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO. MADE IN U.S.A.
ELONGATION OF THE MOON FROM THE SUN
January thru June 1970
June 4
May 5
May 6
April 6
March 8
March 7
Degrees
February 6
January 8
1970

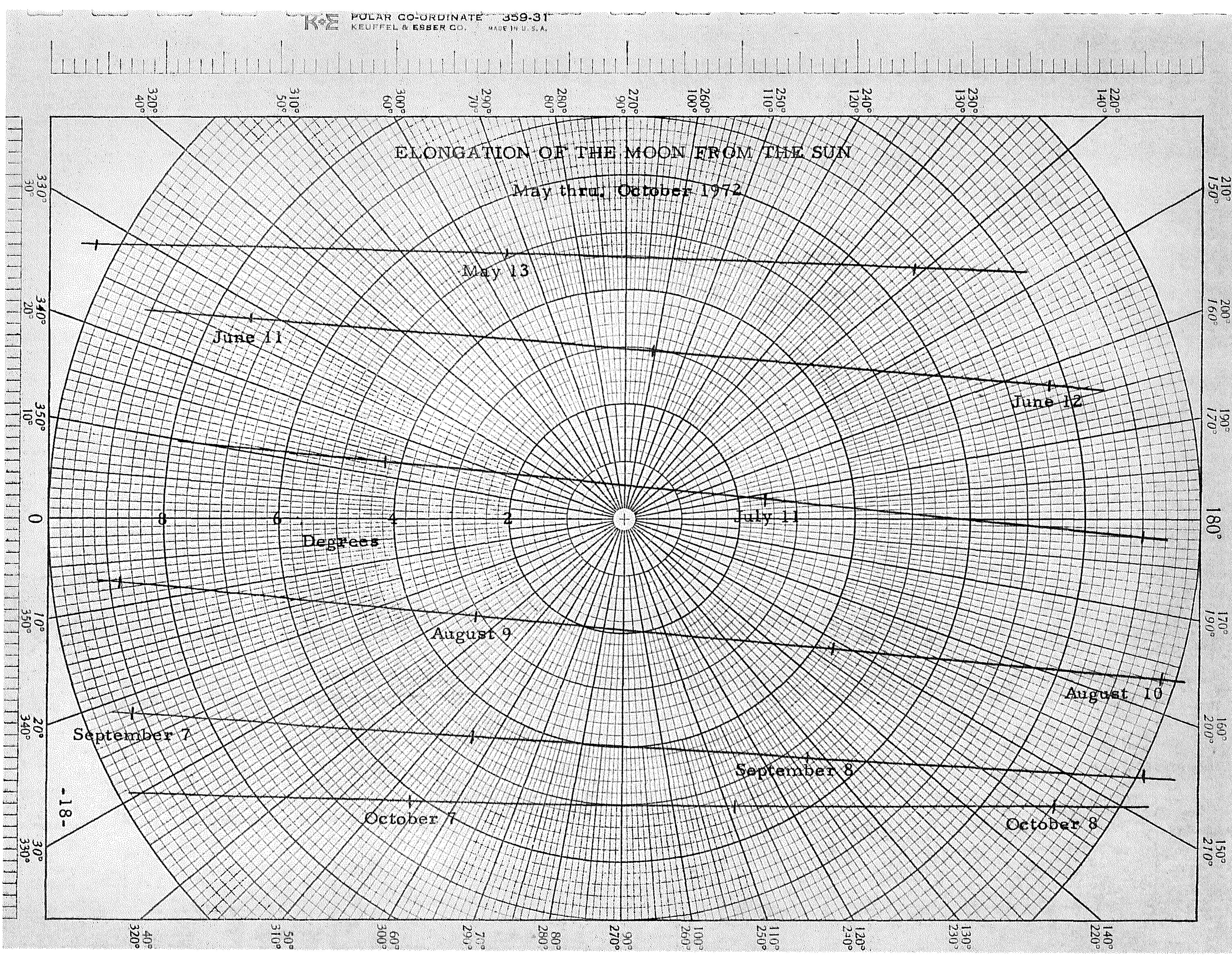

ELONGATION OF THE MOON FROM THE SUN
1970
July thru November
July 3
July 4
August 1
Aug. 2
1970
2
4
6
8
Degrees
September 1
September 30
Sept. 31
October 30
Oct. 31
November 29
1970
K+E POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO. MADE IN U.S.A.

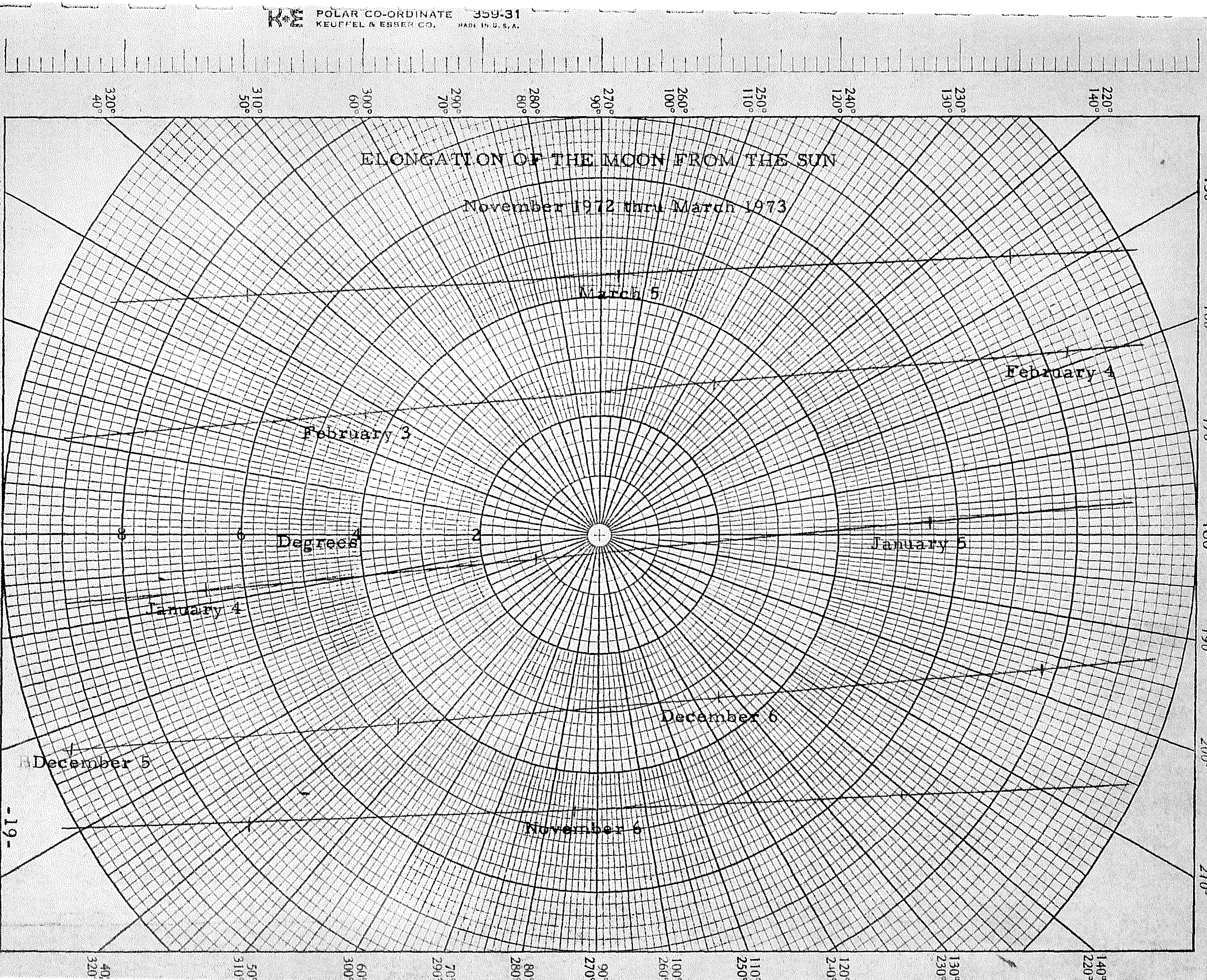

ELONGATION OF THE MOON FROM THE SUN
Dec. 1970 -Apr. 1971
April 25
March 27
Feb. 26
February 25
January 27 1971
Dec. 29/70
December 28, 1970
Degrees
2
4
6
8
0
180°
K+E POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO. MADE IN U.S.A.

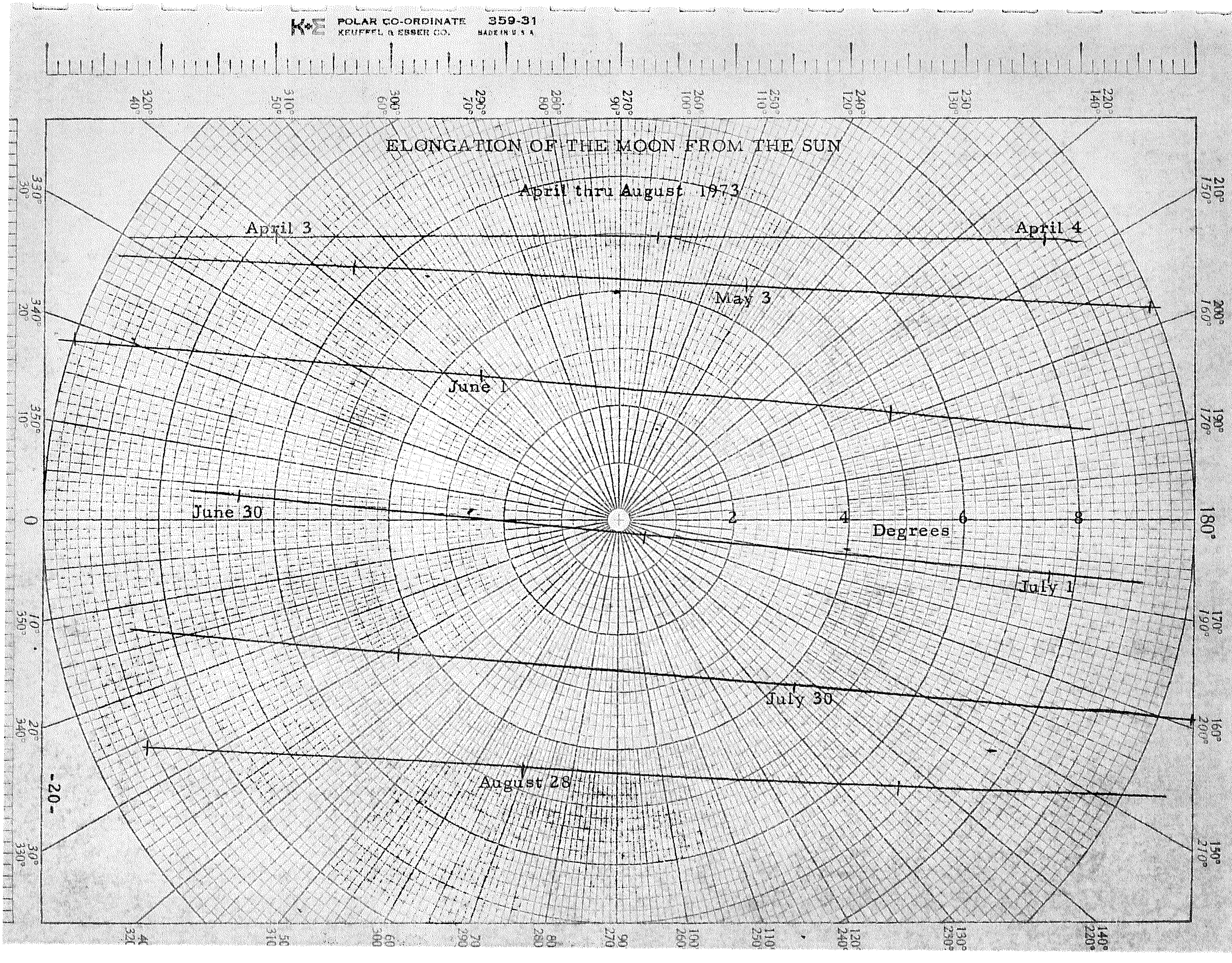


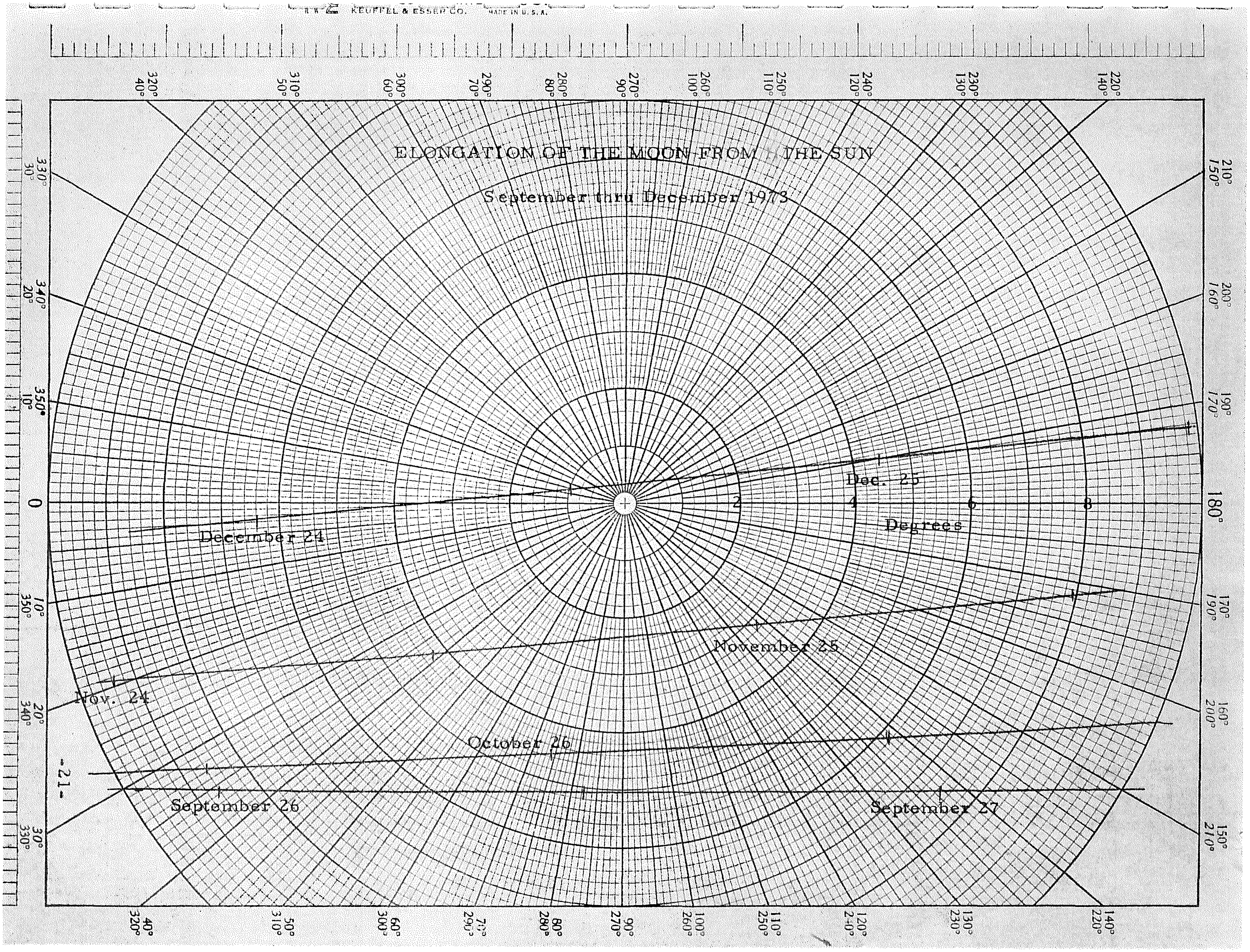
ELONGATION OF THE MOON FROM THE SUN
May - October 1971
May 24
May 25
June 23
July 22
1971
2
4
6
8
Degrees
August 21
September 19
September 20
October 19
October 20


ELONGATION OF THE MOON FROM THE SUN
November 1971 to April 1972
April 14
March 16
March 15
February 15
8
6
4
2
2
4
6
0
180°
Degrees
January 17
January 16/72
December 18, 1971
December 17/71
November 18, 1971


POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO. MADE IN U.S.A.
ELONGATION OF THE MOON FROM THE SUN
May thru, October 1972
May 13
June 11
June 12
July 11
August 9
August 10
September 7
September 8
October 7
October 8
Degrees
8
6
4
2
0
180°


ELONGATION OF THE MOON FROM THE SUN
November 1972 thru March 1973
March 5
February 4
February 3
Degrees
8
6
4
2
0
180°
January 5
January 4
December 6
December 5
November 6
POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO.
MADE IN U.S.A.


K+E POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO. MADE IN U.S.A.
ELONGATION OF THE MOON FROM THE SUN
April thru August 1973
April 3
April 4
May 3
June 1
June 30
July 1
July 30
August 28
Degrees
2
4
6
8
0
180°


ELONGATION OF THE MOON FROM THE SUN
September thru December 1973
Dec. 25
December 24
Degrees
2
4
6
8
0
180°
November 25
Nov. 24
October 26
September 26
September 27